(12) UK Patent Application (19) GB (11) 2 239 856 (13) A

(43) Date of A publication 17.07.1991

(21) Application No 9000727.9

(22) Date of filing 12.01.1990

(51) INT CL[5]
B25J 9/10

(52) UK CL (Edition K)
B8H HDV H560
U1S S1881 S2088

(56) Documents cited
GB 2167038 A

(58) Field of search
UK CL (Edition J) B8H HDV HPD
INT CL[4] B25J

(71) Applicant
ATS Automation Tooling Systems Inc

(Incorporated in Canada – Ontario)

80 Alpine Road, Kitchener, Ontario, N2E 1A1, Canada

(72) Inventor
Klaus D. Woerner

(74) Agent and/or Address for Service
Anthony Asquith
Evans Dodd & Tooth, 5 Balfour Place, Mount Street, London, W1Y 5RG, United Kingdom

(54) Manipulator

(57) A quill assembly for an article-handling apparatus for both holding an article in a fixed position adjacent a workpiece on the bed of the apparatus and performing an operation on the article while at that position. A first portion of the quill assembly is supported on the frame of the apparatus, and is adapted to move relative to the frame for performing the operation on the article. A second portion of the quill assembly is supported on the first portion, and is adapted to move relative to the first portion for holding the article in the fixed position. The quill assembly has particular application to the attachment of a semiconductor chip package to a printed circuit board; in that case, a heater assembly 55 on the first portion of the quill assembly solders the leads of the package to the board while the package is supported by a holding means, e.g. vacuum chuck 29 on the second portion of the quill assembly. Constant force on the workpiece is achieved by a load cell 86 co-operating with lead screw 70 and bias springs 88.

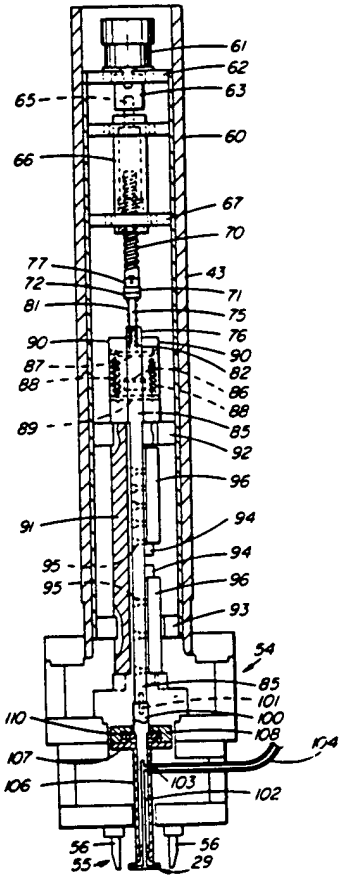

FIG. 2

GB 2 239 856 A

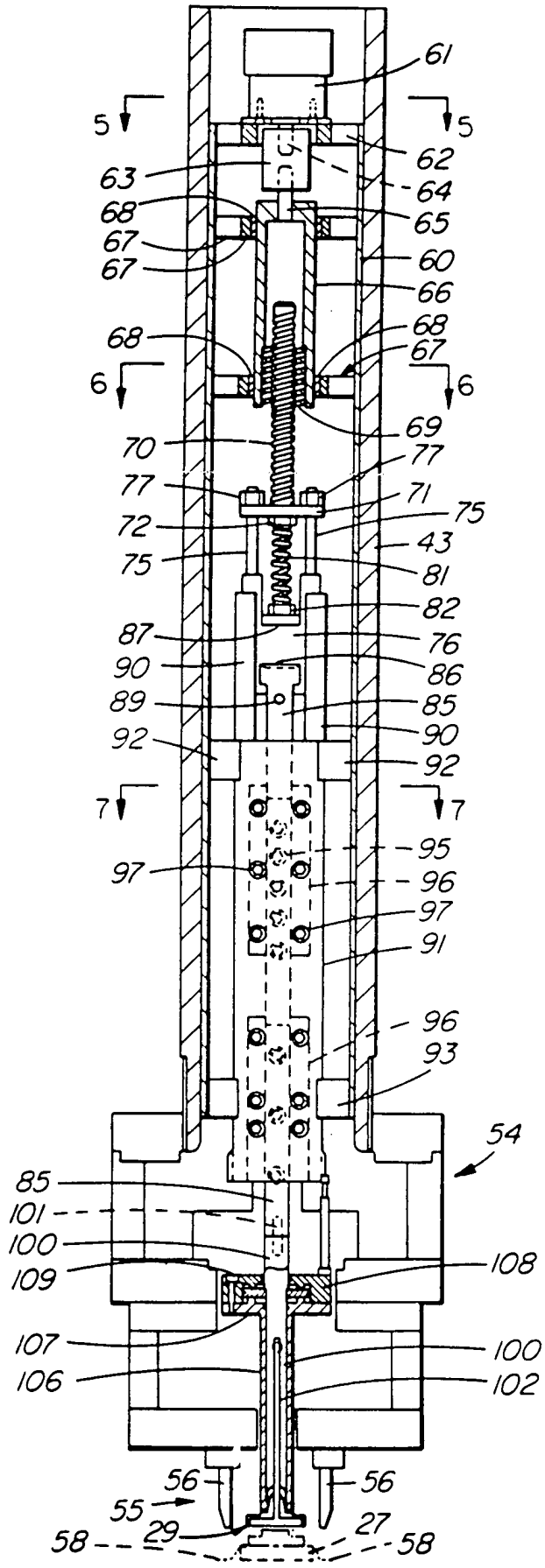
61
5
5
62
63
64
68
65
67
60
67
66
68
68
67
6
6
69
70
77
77
71
72
75
75
43
81
82
87
76
90
86
89
85
90
92
92
7
7
95
97
96
97
91
96
93
54
85
101
100
108
109
107
100
106
102
56
56
55
29
27
58
58

FIG. 1

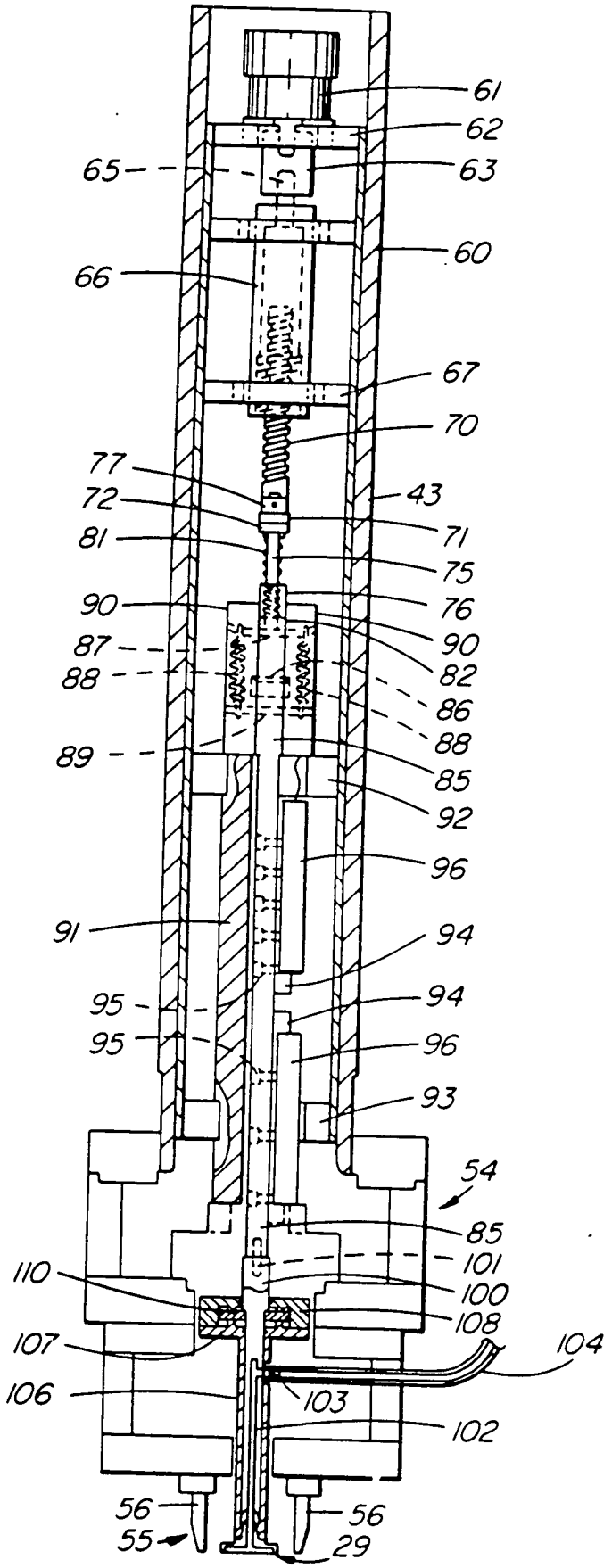
61
62
65
63
60
66
67
70
77
72
43
71
81
75
90
76
90
87
82
88
86
88
89
85
92
96
91
94
95
94
95
96
93
54
85
101
110
100
108
107
104
106
103
102
56
56
55
29

FIG. 2

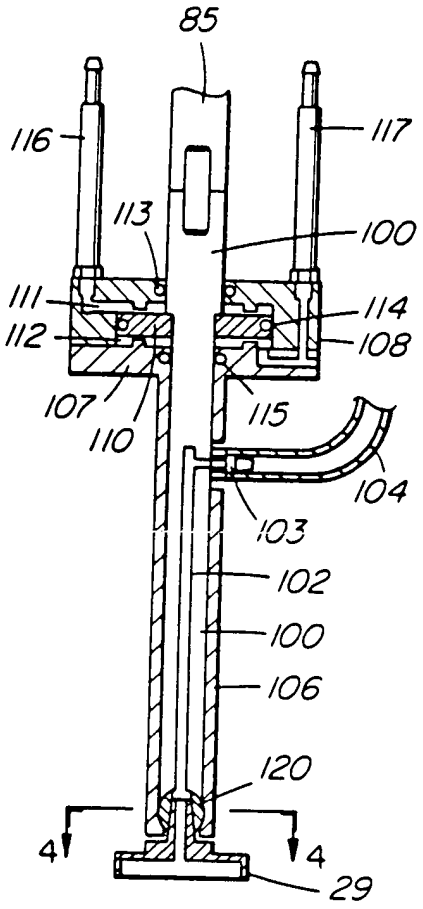

FIG. 3

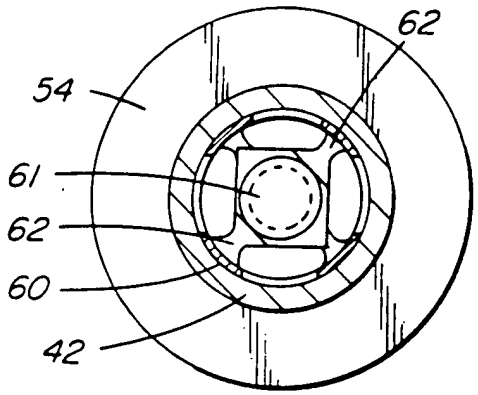

FIG. 5

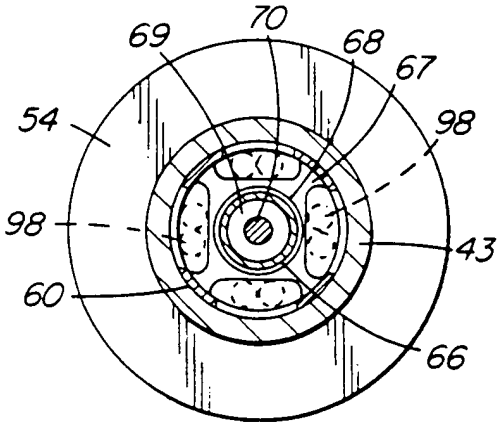

FIG. 6

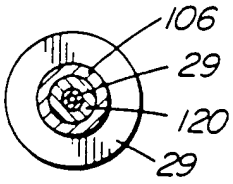

FIG. 4

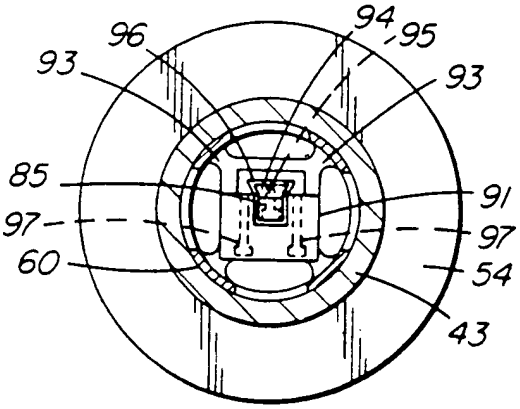

FIG. 7

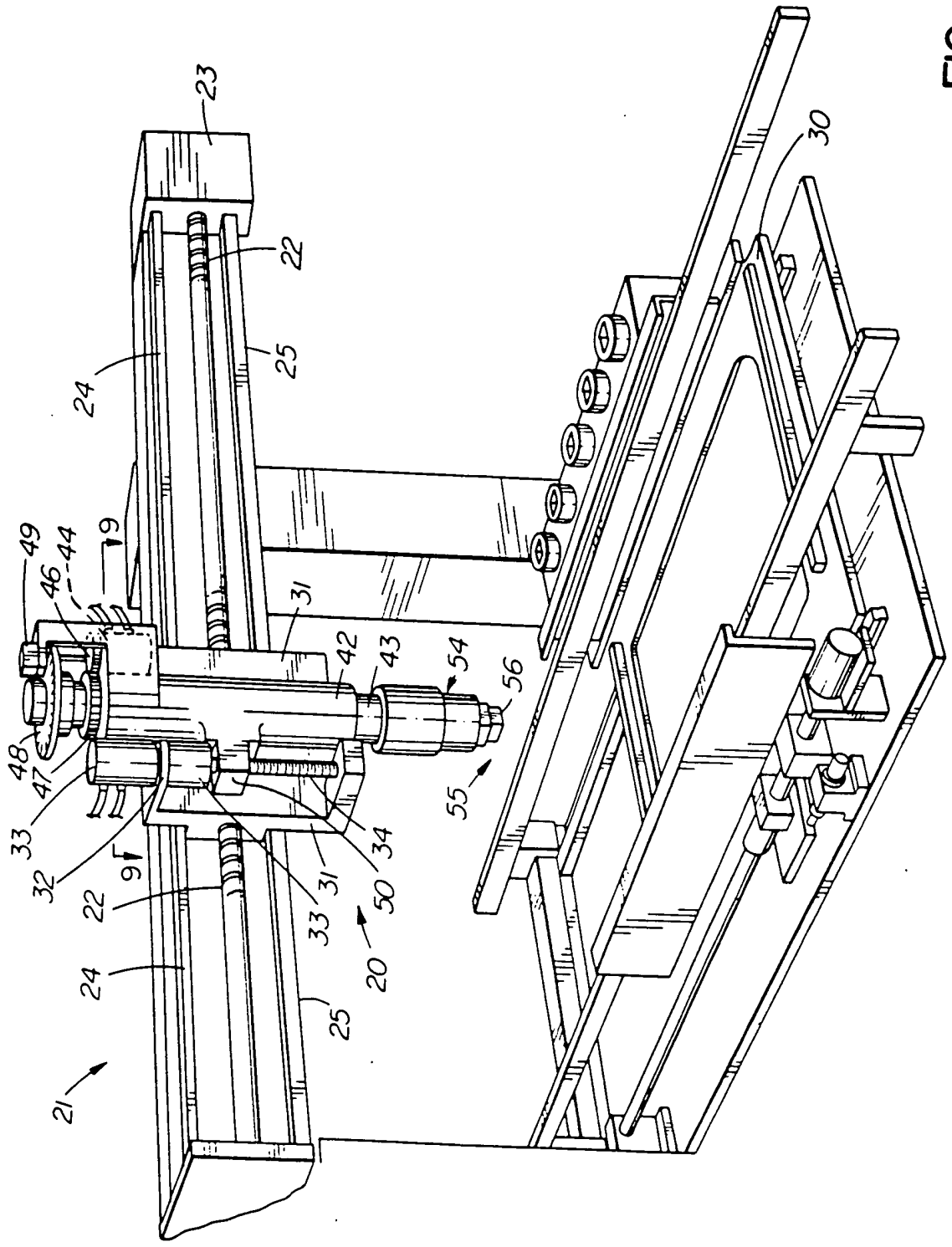
23
22
24
25
30
49
44
46
19
31
42
43
54
56
48
47
33
32
9
22
24
25
21
31
33
50
20
34
55

FIG. 8

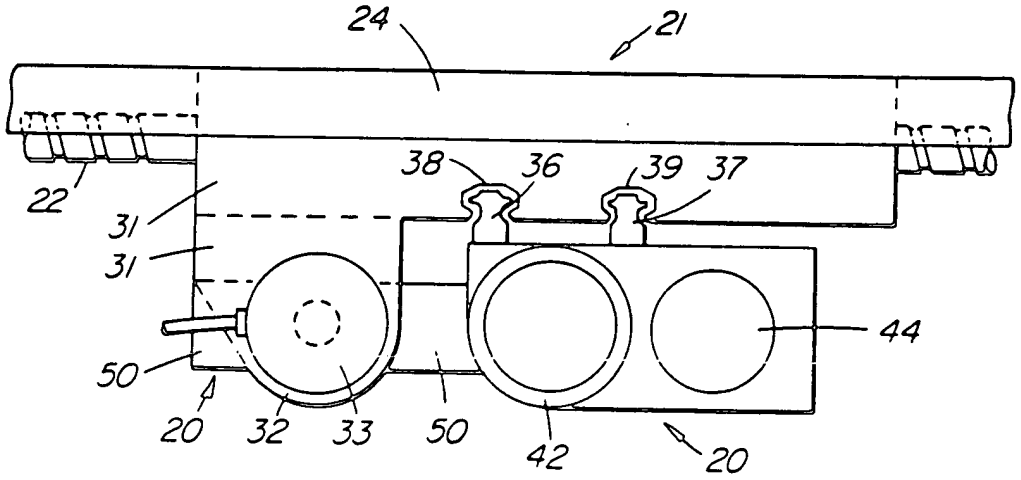

FIG. 9

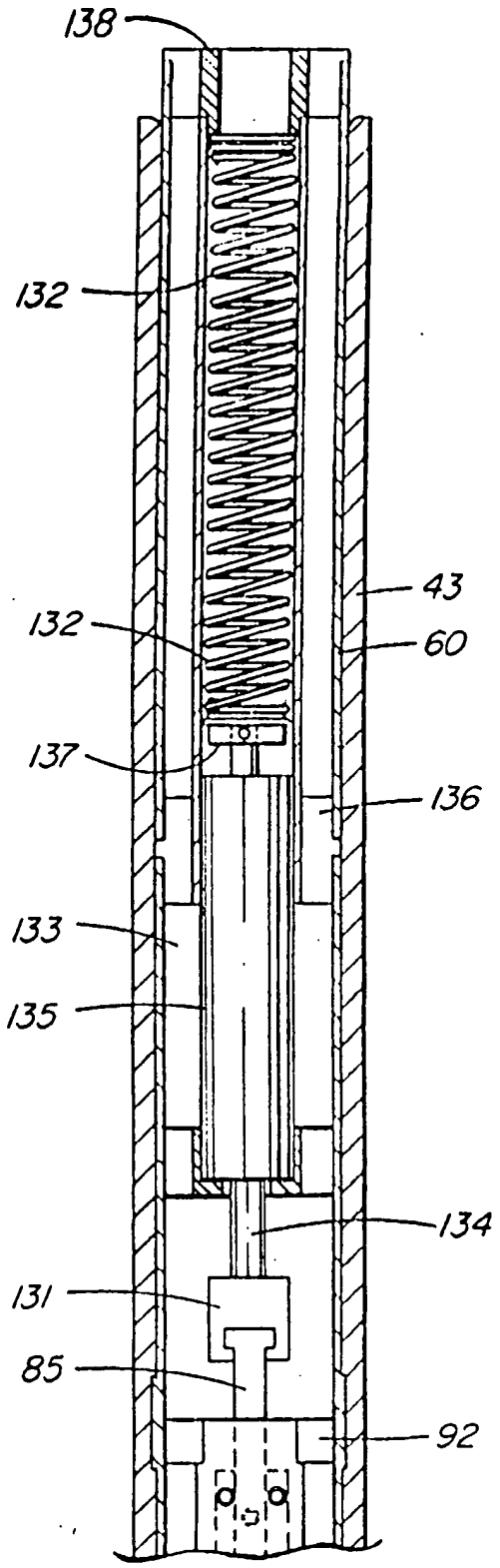

FIG. 10

QUILL ASSEMBLY FOR ARTICLE HANDLING APPARATUS

This invention relates to a quill assembly that may be fitted to an article-handling apparatus, and more particularly, to a quill assembly that may be used both to hold an article in a fixed position adjacent a workpiece on the bed of the apparatus and to perform an operation on the article while at that position.

Robotic devices are now in common use in various industrial processes such as, for instance, the production of printed circuit boards. Such devices have multiple functions. For instance, a robotic device may be used to transport an article from one assembly area to another. Alternatively, the device may be employed to perform an assembly step, such as soldering or drilling, on an article that is supported at a work station. There are obvious advantages to having, where possible, one robotic device perform multiple functions.

One area of technology where it has been found feasible to combine transport and assembly steps in a single robotic device relates to the surface mount placement of packaged semiconductor chips onto printed circuit boards. One common type of package used for such chips is referred to as the TAB (Tape Automated Bond) package, which has a generally square profile with multiple pre-soldered "gull-wing style" leads extending from each of its four sides. The leads on TAB packages are now usually attached to printed circuit boards by a process referred to as "hot bar soldering", which involves the placement of one or more heated bars against the pre-soldered leads of a package while the package is held in position on a circuit board. The mechanism of the invention is capable of performing the dual functions of both supporting a package in a fixed position adjacent the board and attaching the package to the board.

The invention involves a quill assembly adapted to be fitted to an apparatus for both holding an article in a fixed position adjacent a workpiece on the bed of the apparatus and performing an operation on the article while at that position. The quill assembly comprises a frame member, a first member, a second member, a third member, a first actuator means, a second actuator means, a bias element and a sensing element. The frame member is supported on the apparatus so as to remain at a fixed distance from the bed of the apparatus. The first member is supported on the frame member and adapted to move relative to the frame member in a direction normal to the bed of the apparatus. The first actuator means moves the first member relative to the frame member. The second member is supported on the first member and adapted to move relative to the first member in a direction normal to the bed of the apparatus. The second actuator means moves the second member relative to the first member. The third member, which has a means on its one end for holding the article, is supported on the first member and adapted to move relative to the first member in a direction normal to the bed of the apparatus. The bias element is positioned between the second member and the other end of the third member for holding those members in a relative equilibrium position. The sensing element senses movement away from the relative equilibrium position between those members as the third member is stopped it its movement toward the bed of the apparatus. The sensing element is connected to the second actuator means for signalling the second actuator means to move the second member relative to the first member so as maintain the second and third members in their relative equilibrium position. The sensing element may be a piezoelectric load sensing cell.

The first actuator means may comprise a first electric motor, a screw member and a nut member. The first

motor is connected to one of the first member and frame member. The screw member is connected to the rotor of the first motor to rotate in-line therewith. The nut member is connected to the other of the first member and the frame member. The screw member extends through the nut member such that actuation of the first motor results in the first member moving relative to the frame member.

The second actuator means may comprise a second electric motor, a nut member and a screw member. The second motor is connected to one of the first member and the second member. The nut member is connected to a rotor of the second motor to rotate in-line therewith. The screw member extends through the nut member and is connected to the other of the first member and the second member. Actuation of the second motor results in the first member moving relative to the second member.

The holding means on the one end of the third member may be a pneumatic suction cup, and the article adapted to be held by the suction cup may be a packaged semiconductor chip. The workpiece may be a printed circuit board. The one end of the first member adjacent the one end of the third member is adapted to hold a series of heater bars for soldering the leads of the chip to the circuit board. The frame member may be supported on the apparatus in such a manner that the frame member may be moved parallel to the bed of the apparatus.

The invention will next be described by means of preferred embodiments, utilizing the accompanying drawings in which:

Figure 1 is a sectioned first side view of a first portion of the quill assembly of the invention.

Figure 2 is a sectioned second side view of the first portion of the quill assembly, the view extending normal to the view of Figure 1.

Figure 3 is a sectioned side view of that part of the first portion of the quill assembly that is adapted to secure an article to the arm mechanism.

Figure 4 is a cross-sectional view of the part of the first portion of the quill assembly shown in Figure 3, the view being taken on the line 4-4 in Figure 3.

Figure 5 is a first cross-sectional view of the first portion of the quill assembly, the view being taken on the line 5-5 in Figure 1.

Figure 6 is a second cross-sectional view of the first portion of the quill assembly, the view being taken on the line 6-6 in Figure 1.

Figure 7 is a third cross-sectional view of the first portion of the quill assembly, the view being taken on line 7-7 in Figure 1.

Figure 8 is a perspective view of an apparatus utilizing the quill assembly of the invention.

Figure 9 is a cross-sectional view of the apparatus of Figure 8, the view being taken on the line 9-9 in Figure 8.

Figure 10 is a cross-sectional view of an alternative embodiment.

With reference to Figures 8 and 9, a quill assembly generally designated as 20 is mounted for horizontal movement on a supporting carriage generally designated as 21. Quill assembly 20 is moved on carriage 21 by rotation of a ball screw 22 which passes through a complementary thread within quill assembly 20. A motor (not shown) within an end housing 23 rotates ball screw 22. A set of guide members 24 and 25, each extending parallel to ball screw 22, are used to stabilize the horizontal movement of quill assembly 20.

The quill assembly 20 is movable between a pick-up position at the right end of carriage 21 in Figure 8 and the deposition position at which quill assembly 20 sits in

that figure. Assembly 20 picks up, for example, a TAB package 27 at the pick-up position by means of a swivelling suction cup member 29, as shown in outline in Figure 1 and more fully described subsequently, and then carries that package to the deposition position. A support platform 30, movable in a direction normal to carriage 21, is adapted to carry a printed circuit board on which TAB package 27 is to be mounted.

The ball screw 22 extends through a frame member 31 of quill assembly 20 and engages a complementary thread within that member, as earlier mentioned. The frame member 31 has a profile that is complementary to the profile on the guide members 24 and 25. Mounted on frame member 31 by a band 32 is a motor 33 which has its rotor connected in-line with a ball screw 34 which extends vertically. With the exception of frame member 31, motor 33, and ball screw 34, the remaining parts of quill assembly 20 move vertically as a single unit; that unit has a pair of guide members 36 and 37 each fitted to slide within a respective one of a pair of vertical grooves 38 and 39 in frame member 31. Outer housing 42 has a shoulder 50 with a threaded bore for receiving ball screw 34. Actuation of motor 33 results in movement of housing 42 along the vertical grooves 38 and 39.

An outer cylindrical housing 42 of quill assembly 20 has an inner cylinder 43 mounted concentrically within it. A motor 44 is mounted to an upper portion of outer housing 42 such that the rotor of motor 44 extends parallel to the axis of inner cylinder 43. A gear wheel 46 connected to the rotor of motor 44 is positioned such that its teeth mesh with the teeth of a gear wheel 47 connected to inner cylinder 43. Inner cylinder 43 also has connected to it a disc 48 with radial calibrations markings, as shown in Figure 8. An optical scanning unit 49 is mounted to housing 41 to sense the angular position of inner cylinder

43; that angular position can then be modified by actuation of motor 44.

Inner cylinder 43 of quill assembly 20 is shown enlarged in Figures 1 and 2; those figures do not show the gear 47 or disc 48 that are connected to the upper end of cylinder 43. Connected to the lower end of cylinder 43 is a heater bar assembly 55 including floating heater bars 56, similar to the type which has been generally described in U.S. Patent Application No. 07/246,796, filed on September 20, 1988 and entitled "Method and Apparatus for Reflow Soldering of Electrical Component Leads, including Floating Heater Bar". The lower end of heater bar assembly comprises four spring-mounted heater bars 56 arranged such that each bar 56 forms one of the sides of a rectangle. A series of heater bar assemblies of differing sizes may be used, the particular assembly in use at any given time depending on the outer dimensions of the TAB package 27 being carried on quill assembly 20. Each assembly 55 is sized such that each of its four heater bars 56 is adapted to extend across all of the gullwing-shaped leads 58 that extend from a respective one of the four sides of the corresponding TAB package 27.

As shown in Figures 1 and 2, a tube 60 runs along the inner surface of inner cylinder 43. A motor 61 is supported on a cross-member 62 connected to one end of tube 60. A coupling 63 connects the rotor 64 of motor 61 to an in-line sleeve shaft 65 which extends symmetrically from one end of a cylindrical sleeve 66, the sleeve 66 thus being rotatable with rotor 64 by motor 61. Sleeve 66 is positioned within tube 60 by a pair of cross-members 67, each having a bronze ring 68 sitting between it and sleeve 66. The other end of sleeve 66 is fitted with a ball nut 69 through which extends a complementary ball screw 70. Rotation of sleeve 66 causes ball screw 70 to move in or out of sleeve 66.

The ball screw 70 has a threaded end portion (not shown) which extends through a hole centrally positioned in a plate 71, a nut 72 fitted on the threaded end portion securing plate 71 to ball screw 70. A pair of guide rods 75 are press fitted into a yoke 76. Each guide rod 75 extends through a hole in a respective opposite end of plate 71. A nut 77 is secured to a threaded end portion of each guide rod 75 to limit movement of plate 71 relative to yoke 76. The upper end of a spring 81 is fitted over the threaded end portion of ball screw 70. The lower end of spring 81 is fitted over a threaded rod (not shown) which extends out of the top side of yoke 76, the bottom end of spring 81 abutting a nut 82 on the threaded rod. Slide member 85 is fitted into a complementary aperture in the lower side of yoke 76. A load cell 86 is fitted to the upper end of slide member 85 to sense pressure exerted by the one on the other. The nut 82 secures a plate 87 to the top of the yoke 76. A pair of springs 88 each extend between a respective opposite end of the plate 87 and a respective opposite end of a rod 89 extending centrally through the slide member 85; the springs 88 are utilized for maintaining a positive pressure on load cell 86. Four guide supports 90 extend in parallel spaced relation to each other in a generally square configuration for restricting yoke 76 to movement parallel to tube 60. The four supports 90 are integrally connected to one end of a rectangular beam 91 to form a support structure, that structure being positioned within tube 60 by a pair of cross-members 92 and 93.

The slide member 85 is slidably attached to a first portion 94 of a pair of slide bearings by a first series of bolts 95. The first portion 94 of each slide bearing and a second portion 96 of the bearing each have a facing elongated channel within which are mounted a series of roller bearings (not shown). The second portion 96 of

each slide bearing is attached to the beam 91 by a second series of bolts 97. The series of circles 98 shown in outline adjacent to the perimeter of cross-member 67 in Figure 6 represent wires that extend between inner cylinder 43 and tube 60 for supplying electrical current to the heater bars 56.

The slide member 85 is connected at its lower end to extend in-line with a cylindrical element 100, the connection being by means of a threaded rod 101. A bore 102 extends centrally through the lower portion of element 100, the upper end of bore 102 being connected through a fixture 103 to a flexible vacuum hose 104. Fitted to the slide member over element 100 is a hollow cylinder 106. The one end of cylinder 106 has a integral annular flange 107 which is secured to an annular ring 108 by a series of screws 109. An annular piston 110, which is press fitted to cylindrical element 100, is sandwiched between flange 107 and ring 108. The cylinder 106 moves relative to cylindrical element 100 whenever a pressure differential exists between the annular chambers 111 and 112. Annular sealing rings 113, 114, and 115 provide seals for air entering chambers 111 and 112 through the fixtures 116 and 117.

The lower ends of cylindrical element 100 and cylinder 106 are contoured to form a spherical chamber within which sits a spherical member 120. Fitted into spherical member 120 is a suction cup member 29. The bore 102 is in flow communication with a flow channel and vacuum chamber within cup member 29. When cylinder 106 assumes a first position relative to cylindrical element 100, spherical member 120 and cup member 29 are free to rotate; when cylinder 106 assumes a second position, spherical member 120 is prevented from rotating. By applying a differential air pressure to the fixtures 116 and 117 the

suction cup member 29 can be maintained in a fixed orientation.

The package 27 sometimes has a top surface that is not parallel to its bottom surface. For instance, if a heat sink defines the top of the package the epoxy may not be applied evenly between the heat sink and the remainder of the package. When quill assembly 20 is lowered onto package 27 in the pick-up position described earlier, cylinder 106 is positioned relative to cylindrical element 100 such that cup member 29 is free to rotate to orient its suction surface to extent parallel with the top surface of package 27. Variation of the air pressure entering one or both of fixtures 116 and 117 then results in cylinder 106 moving relative to cylindrical element 100 to prevent spherical member 120 and cup member 29 from any further rotation. When the package 27 is subsequently deposited on a printed circuit board resting on the support platform 30, the bottom surface of the package will extend parallel to the surface of that board.

The sequence of operations of the apparatus is as follows. The quill assembly 20 is moved to the pick-up position, such that it sits directly above the package 27 that is being picked up. The pressure into apertures 116 and 117 is such that spherical member 120 and cup member 29 are free to rotate. The motor 33 is then actuated to move the vertically-movable portion of quill assembly 20 toward package 27. The suction surface of cup member 29 contacts the top of package 27, and cup member 29 rotates until the suction surface is flush with the top surface of package 27. As housing 41 continues downward, the spring 81 becomes compressed and exerts increasing pressure on load cell 86. Load cell 86 transmits its signal to the control system of the apparatus, which in turn actuates motor 61 to rotate sleeve 66. Screw ball 70 then moves into sleeve 66 to relieve the pressure on load cell 86. This arrangement

is calibrated such that only a limited force of typically approximately four ounces is experienced by package 27. It is also calibrated such that motor 33 stops within a small distance of the expected contact with package 27. Each of the heater bars 56 is then adjacent one of the sides of package 27.

Then, the pressure into apertures 116 and 117 is modified such that cup member 29 is prevented from rotating, and suction is applied to hose 104 for holding package 27 on cup member 29. The motor 33 is then actuated to raise the vertically-movable portion of quill assembly 20 and package 27, after which ball screw 22 is rotated to move quill assembly 20 such that it sits above the position on the printed circuit board at which package 27 is to be deposited.

The motor 33 is then actuated to lower the vertically-movable portion of quill assembly 20 toward the printed circuit board. The package 27 comes into contact with the printed circuit board, and spring 81 begins to compress. Load cell 86 senses the increased pressure and sends a signal to the control system of the apparatus. Motor 61 is then actuated to maintain the limited force on package 27. The heater bars 56 continue to move downward around the periphery of the package 27. Prior calibration of the apparatus results in the motor 33 stopping as soon as the heater bars 56 begin to press the leads 58 on package 27 against the circuit board. The spring-mounting of each of the heater bars 56 prevents damage to the leads and circuit board. The heater bars 56 are then activated to momentarily reflow solder the leads 58, each lead 58 being thereby soldered to a respective metal trace on the circuit board. The suction is then removed from hose 104, and the motor 33 is actuated to raise the vertically-movable portion of quill assembly 20; as it rises, the pressure on load cell 86 is reduced and motor 61 is

automatically actuated to move screw ball 70 out of sleeve 66 to return the pressure on load cell 86 to its equilibrium value. The pressure into apertures 116 and 117 is then adjusted to allow cup member 29 to again freely rotate. The quill assembly is then in a state ready for fetching another package 27.

Figure 10 illustrates an alternate actuating means for moving cup member 29 relative to inner cylinder 43. In this arrangement, a slide member 85 presses against a yoke 131. Between yoke 131 and a spring 132 is a direct current magnetic linear motor generally designated 133. The motor 133 has a shaft 134 extending through a body 135; neither part rotates. The body 135 is fixed to tube 60 by a cross-member 136. Shaft 134 has its one end connected to yoke 131 and its other end connected to a disc 137 that supports one end of the spring 132. The other end of spring 132 is supported by a cross-member 138 at the top end of tube 60. The steady-state current entering motor 133 is initially adjusted such that a constant force of four ounces is maintained on slide member 130. As inner cylinder 43 moves in a downward direction but the package 27 on cup member 29 is prevented from further movement, shaft 134 moves in an upward direction relative to body 135 and spring 132 is compressed. Due to a property of linear motors, the current entering motor 133 automatically increases as shaft 134 is displaced; that extra current produces a force which acts to counter the force created by the compression of spring 132. The result is that a constant force is maintained on slide member 130 regardless of the position assumed by that slide member. In this case, a force of four ounces is maintained on package 27 after cup member 29 is prevented from further downward movement.

CLAIMS:

1. A quill assembly adapted to be fitted to an apparatus, the quill assembly being adapted both to hold an article in a fixed position adjacent a workpiece on the bed of the apparatus and to perform an operation on the article while in that position, the quill assembly comprising:

(a) a frame member supported on the apparatus so as to remain at a fixed distance from the bed of the apparatus;

(b) a first member supported on the frame member and adapted to move relative to the frame member in a direction normal to the bed of the apparatus;

(c) a first actuator means for moving the first member relative to the frame member;

(d) a second member supported on the first member and adapted to move relative to the first member in a direction normal to the bed of the apparatus;

(e) a second actuator means for moving the second member relative to the first member;

(f) a third member supported on the first member and adapted to move relative to the first member in a direction normal to the bed of the apparatus, the third member having a means on its one end for holding the article;

(g) a bias element positioned between the second member and the other end of the third member for maintaining those members in a relative equilibrium position; and,

(h) a sensing element for sensing movement away from the relative equilibrium position between those members as the third member is stopped in its movement toward the bed of the apparatus, the sensing element being connected to the second actuator means for signalling the second actuator means to move the second member relative to

the first member so as to maintain the second and third members in their relative equilibrium position.

2. A quill assembly as in claim 1, wherein the bias element is a spring and the sensing element is a piezoelectric load sensing cell.

3. A quill assembly as in claim 1, wherein the first actuator means comprises a first electric motor connected to one of the first member and the frame member, a screw member connected to the rotor of the first motor to rotate in-line therewith, and a nut member connected to the other of the first member and the frame member, and the screw member extending through the nut member such that actuation of the first motor results in the first member moving relative to the frame member.

4. A quill assembly as in claim 1, wherein the second actuator means comprises a second electric motor connected to one of the first member and the second member, a nut member connected to a rotor of the second motor to rotate in-line therewith, and a screw member extending through the nut member and connected to the other of the first member and the second member, and wherein actuation of the second motor results in the first member moving relative to the second member.

5. A quill assembly as in claim 1, wherein the holding means on the one end of the third member is a pneumatic suction cup.

6. A quill assembly as in claim 5, wherein the article adapted to be held by the suction cup is a packaged semiconductor chip.

7. A quill assembly as in claim 1, wherein the article is a packaged semiconductor chip, wherein the workpiece is a printed circuit board, and wherein the workpiece is a printed circuit board, and wherein the one end of the first member adjacent the one end of the third

member is adapted to hold a series of heater bars for soldering the leads of the chip to the circuit board.

8. A quill assembly as in claim 1, wherein the frame member is supported on the apparatus in such a manner that the frame member may be moved parallel to the bed of the apparatus.

9. A pneumatic holding mechanism adapted to be fitted to an article-handling arm of an apparatus for maintaining an article during handling at a fixed orientation, the mechanism comprising:

(a) a finger adapted to extend normal to a bed of the apparatus, the finger having a suction channel extending longitudinally from a port on the finger to one end of the finger, the one end being more proximate the bed of the apparatus, the port being adapted to be connected to a suction source;

(b) an actuating member fitted on the finger so as to extend normal to the bed of the apparatus, the actuating member having a flange portion on that end more proximate the bed of the apparatus;

(c) a first actuator means for moving the first member relative to the frame member;

(d) a holding member supported on the first member and adapted to move relative to the first member in a direction normal to the bed of the apparatus, the holding member having a means on its one end for holding the article;

(e) a bias element having its one end connected to the first member; and,

(f) a linear motor having a shaft and a body, one of the shaft and the body being connected to the other end of the bias element, the other of the shaft and the body being connected to the other end of the holding member, the

shaft moving relative to the body and compressing the bias element when the first member moves toward the bed of the apparatus but the holding member is stopped from such movement, the linear motor being adapted to provide a force on the bias element equal to the force created by compression of the bias element.

10. Apparatus for moving a tool away from a frame and into contact with a workpiece, characterized by a first member movable away from said frame towards said workpiece by first actuation means, a second member attached to said first member and moveable relative to said first member towards and away from said workpiece by second actuation means, a third member attached to said second member between said second member and said workpiece, said tool being attached to said third member, sensing means between said second and third members for sensing when said third member is being urged towards said second member by virtue of said tool contacting said workpiece, and control means responsive to said sensing means for controlling said first and second actuation means such that when said sensing means indicates contact with said workpiece, said second actuation means moves said second member towards said first member at the same rate and distance as said first member moves towards said workpiece as long as said first member continues to move.

Published 1991 at The Patent Office, State House, 66/71 High Holborn, London WC1R 4TP. Further copies may be obtained from Sales Branch, Unit 6, Nine Mile Point, Cwmfelinfach, Cross Keys, Newport, NP1 7HZ. Printed by Multiplex techniques ltd, St Mary Cray, Kent